

Real-time stress detection and monitoring system using IoT-based physiological signals

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ABSTRACT

Currently, medical experts use psychophysiological questionnaires to evaluate human stress levels during counseling or interviews. Typically, biochemical samples use urine, saliva, and blood samples to identify the effects of stress on the human body. This research explains that stress detection can be done by analyzing psychological signals and the importance of monitoring stress levels. The authors develop research on stress detection based on psychological signals. The system then processes the recorded data; the android application displays the calculation results. The database can also be accessed as a spreadsheet via a web application. The design of real-time stress detection and monitoring using internet of things (IoT) can work well.

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1. INTRODUCTION

Stress is a condition caused by transactions between individuals and the environment that creates a perception of distance between the demands of the situation and the resources in a person's biological, psychological, and social systems [1], [2]. Stress is the natural factor that causes unstable homeostasis [1], [3]. Stress will cause an increase in blood pressure (BP) by a mechanism that triggers an increase in adrenaline levels [4]. Stress will stimulate the sympathetic nerves, causing an increase in BP and heart rate (HR). Stress will increase if peripheral vascular resistance and HR increase, thereby stimulating the sympathetic nerves [1], [4], [5]. The occurrence of stress will react to the body, including increased muscle tension, HR, and BP [5]. Stress that has a positive impact is called eustress. The type of stress is characterized by an increased pulse but without a feeling of threat. Stress that has a negative effect is called distress, characterized by anxiety or concern. This kind of stress can be a short-term or long-term occurrence [6].

Currently, medical experts use psychophysiological questionnaires to evaluate human stress levels during counseling or interviews. However, this is highly dependent on the ability and sensitivity of experts in extracting information on patients. Nowadays, researchers developed scientific tools that are more effective in detecting stress. The methods designed to detect stress include physiological signals and biochemical samples [7], [8]. Typically, biochemical samples use urine, saliva, and blood samples to identify the effects of stress on the human body [7]. Many physiological signals have attracted researchers to develop a stress detection system [7], [9]–[11]. Stress can be triggered by physiological responses, physical activity such as running, and lack of sleep. It causes health problems, namely the effects of chronic stress, such as

hypertension, cardiovascular disease, and memory problems [12], [13]. Symptoms of stress must be detected and monitored earlier to avoid dangerous conditions.

Research by Nakagawa *et al.* [11] developed a non-invasive integrated vital sign using near-infrared (NIR) and far-infrared (IR) cameras. This study measured pulse rate (PR) with high accuracy based on NIR images of human cheeks, measuring the skin temperature of the nose and forehead based on infrared images. Based on these measurements, the integrated system can detect stress effectively. This study found calm and stressed conditions [11]. Ra and Sarath [14] detected stress using HR and galvanic skin response (GSR); the accuracy was 99.5%. Mokhayeri *et al.* [15] studied stress detection utilizing pupil diameter, electrocardiography (ECG), and PhotoPlethysmoGraphy (PPG). This research employed soft computing analysis using an optimization approach to genetic algorithm (GA). Furthermore, they imported it into fuzzy support vector machine (FSVM) to classify stress and relaxation. The experimental results show that physiological signals have great potential for detecting stress and can provide a good classification [15].

Bin *et al.* [16] have developed a real-time stress detection system from physiological signals, namely PR and temperature. The results of this study can record a person's stress level with the k-nearest neighbor (k-NN) technique, bayesian networks, and fuzzy logic. The development of this study uses the LM35 because it is easy to use, has lower costs, and has stable accuracy. For HR detection, this pulse sensor can detect the heart's electrical activity by attaching electrodes to specific locations such as fingertips, feet, chest, and arms [16]. Setiawan *et al.* [17] have succeeded in developing an internet of things (IoT) based stress diagnostic and medical record using the fuzzy logic method. The sensors measured body temperature, GSR, and HR. Fifteen subjects were observed, and the system successfully sent and stored data in the database. The accuracy of the results was 80%.

One of the technologies used for health monitoring was the IoT [18]–[21]. The availability of this data, coupled with modern statistical analysis tools such as machine learning, can drive new standards of health diagnosis [19], [22], [23]. Based on the explanation of stress detection can be done by analyzing psychological signals and the importance of monitoring stress levels, the authors develop research on stress detection based on psychological signals by utilizing IoT to facilitate monitoring.

2. METHOD AND DESIGN IMPLEMENTATION

2.1. Subject sample

The sampling technique was purposive, based on specific characteristics, traits, or things. The number of samples was ten people with inclusion and exclusion criteria. Inclusion criteria include being in good health, not having a history of the disease, and being willing to be a research respondent by filling out a letter of consent. The exclusion criteria included the respondent's fever and unwillingness to take and store the data. Data was collected directly from human respondents and obtained approval from the Politeknik Kesehatan Kemenkes Jakarta II ethics committee.

2.2. Pulse sensor

Pulse sensor works on the principle of plethysmography designed to detect cardiovascular signals from the skin surface based on signal fluctuations influenced by blood flow [17], [24]. Measuring and estimating HR from PPG signals during intense physical activity is challenging because it requires high accuracy. The PPG technique measured HR because it makes the device small and easy to use [25]. The PPG principle is that the skin surface is illuminated by light from a light emitting diode (LED), infrared or red LED. The light that is transmitted or reflected by the skin's surface, collected through a photodiode, is then used to determine changes in blood volume. The photodiode is placed on the other side of the skin surface to detect the transmitted light [26]. In this experiment, the pulse sensor used for HR detection is the MAX30100 sensor. The MAX30100 sensor is an integrated pulse oximetry sensor and HR monitor sensor. The output of the MAX30100 is HR and percentiles of oxygen saturations (SPO₂). This sensor operates from 1.8 V and 3.3 V power [26], [27]. The MAX30100 can be configured via registers, and the digital output data is stored in the device first-in, first-out (FIFO). MAX30100 module is shown in Figure 1.

2.3. Body temperatur sensor

Normal body temperature changes depending on gender, continuous movement, food, fluid use, time of day, and for women during the menstrual cycle phase. The typical body temperature of a healthy adult can rise from 36.5 to 37.2 °C [28]. In this experiment, the temperature detection using a DS18B20 sensor with three pins: the Vcc pin, ground, and data output. The voltage for this sensor to work is +5 V, and the output data from the sensor will go to the digital microcontroller PB5pin shown in Figure 2 [29].

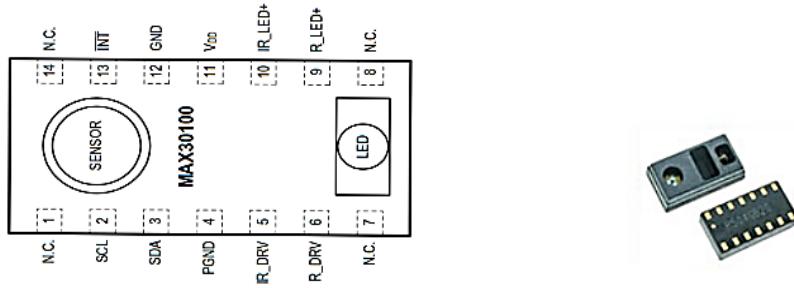


Figure 1. The pin configuration of the MAX30100 sensor [26]

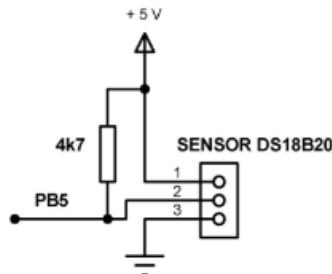


Figure 2. The circuit diagram of the DS18B20 sensor [29]

2.4. System design

Figure 3 explains the design of a real-time stress detection system, which consists of a microcontroller, temperature sensor, and HR sensor. The system as a whole gets power from the 5 V adapter. The DS1820 read the temperature, and the MAX30100 read the HR and SPO2. The ESP32 microcontroller reads the data and then processes it into stress information—the information displayed on the LCD and an android cellphone. We are monitoring via LCD for patients and through applications connected to IoT technology for other parties who need the data remotely.

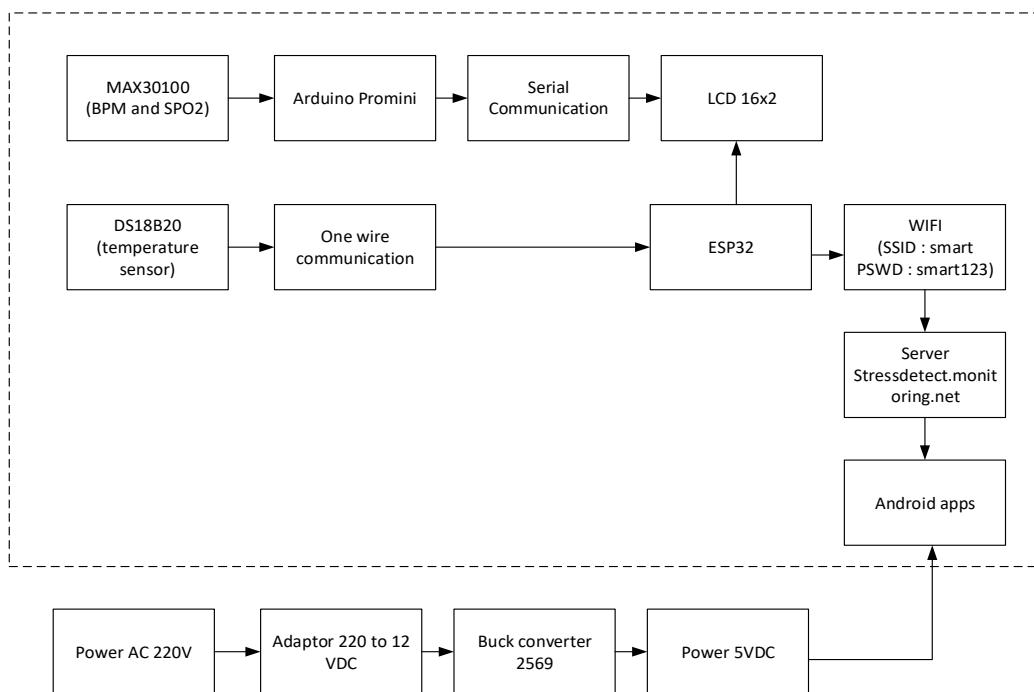


Figure 3. Diagram block of the real-time stress detection and monitoring using IoT

2.5. Hardware design

Hardware design is explained by the circuit drawing in Figure 4. The circuit diagram describes the relationship between each component. A 220 VAC source supplies the system and converts it into a 5 VDC using a step-down transformer adapter. The DS18B20 and the MAX30100 are input to pins A4 and A5 on the Arduino Pro Mini. The information is sent to the cloud database via ESP32.

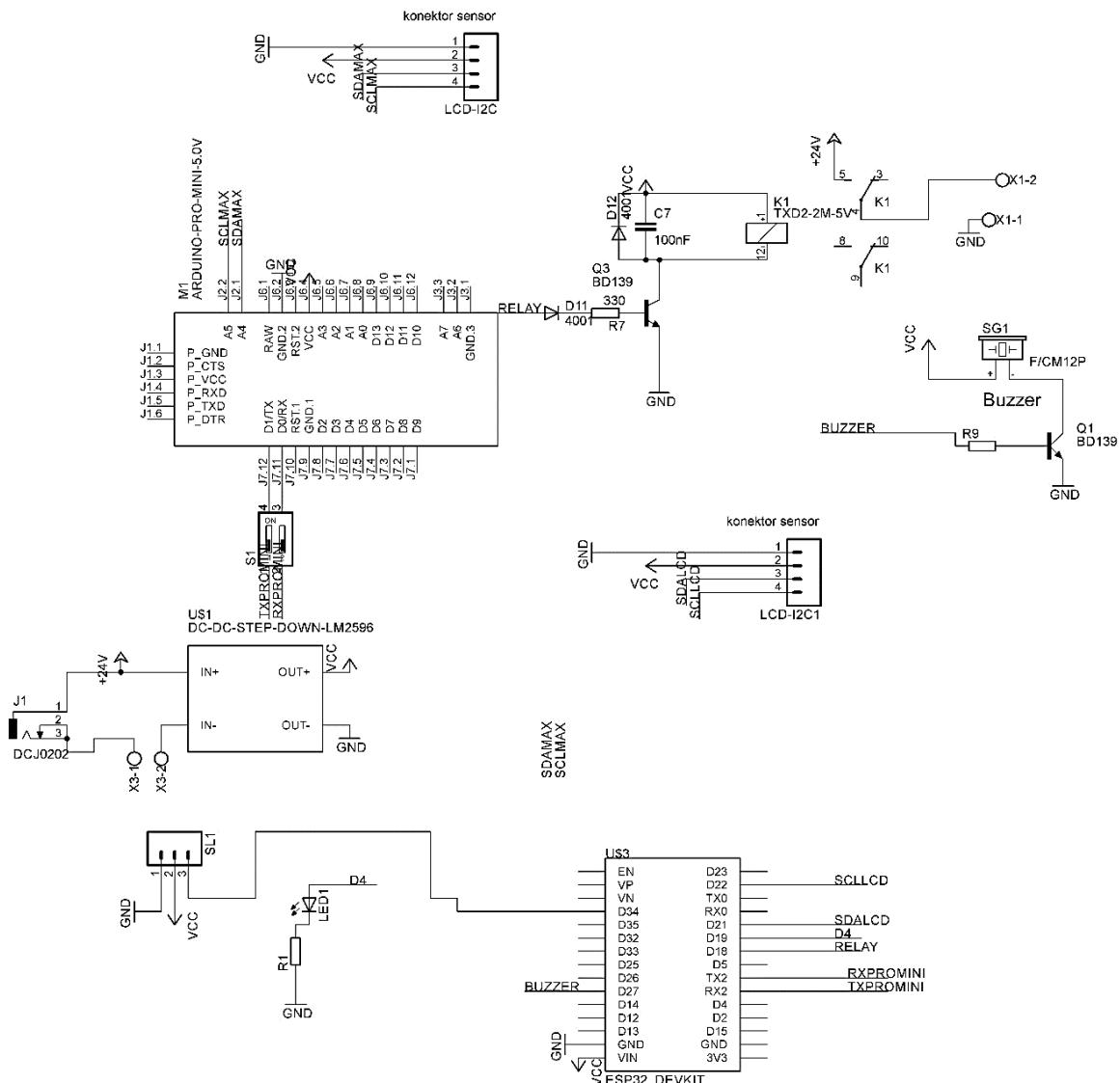


Figure 4. Schematic circuit of real-time stress detection and monitoring using IoT

2.6. Real-time database

The system was developed using firebase type SPARK, a NoSQL database developed by Google and can be used for free. The firebase feature used in this research is the firebase real-time database. The advantage of this feature is that it remains responsive when offline because the data is directly stored in local memory. Once the device is back online, it will accept the changes to the information that has been saved.

2.7. Android base design

This application monitors the values of all measured parameters. It displays the calculation results and stress information based on these parameters. The application is developed using Android Studio. The data showed temperature data in degrees celsius, HR data in beats per minute, SPO2, stress, and normal information conditions.

2.8. Firmware design

The firmware of a system is an essential component that determines its functionality. In the case of this system, the firmware is a program embedded in the Arduino Promini, created using the Arduino IDE. This firmware plays a crucial role in enabling the system to detect stress. To better understand the functioning of the stress detection system, Figure 5 provides a detailed flowchart that describes the various stages involved. By following this flowchart, the system can accurately identify stress levels and provide appropriate feedback to the user. Overall, the effective integration of the firmware and the flowchart makes the stress detection system a reliable and efficient tool for monitoring stress levels.

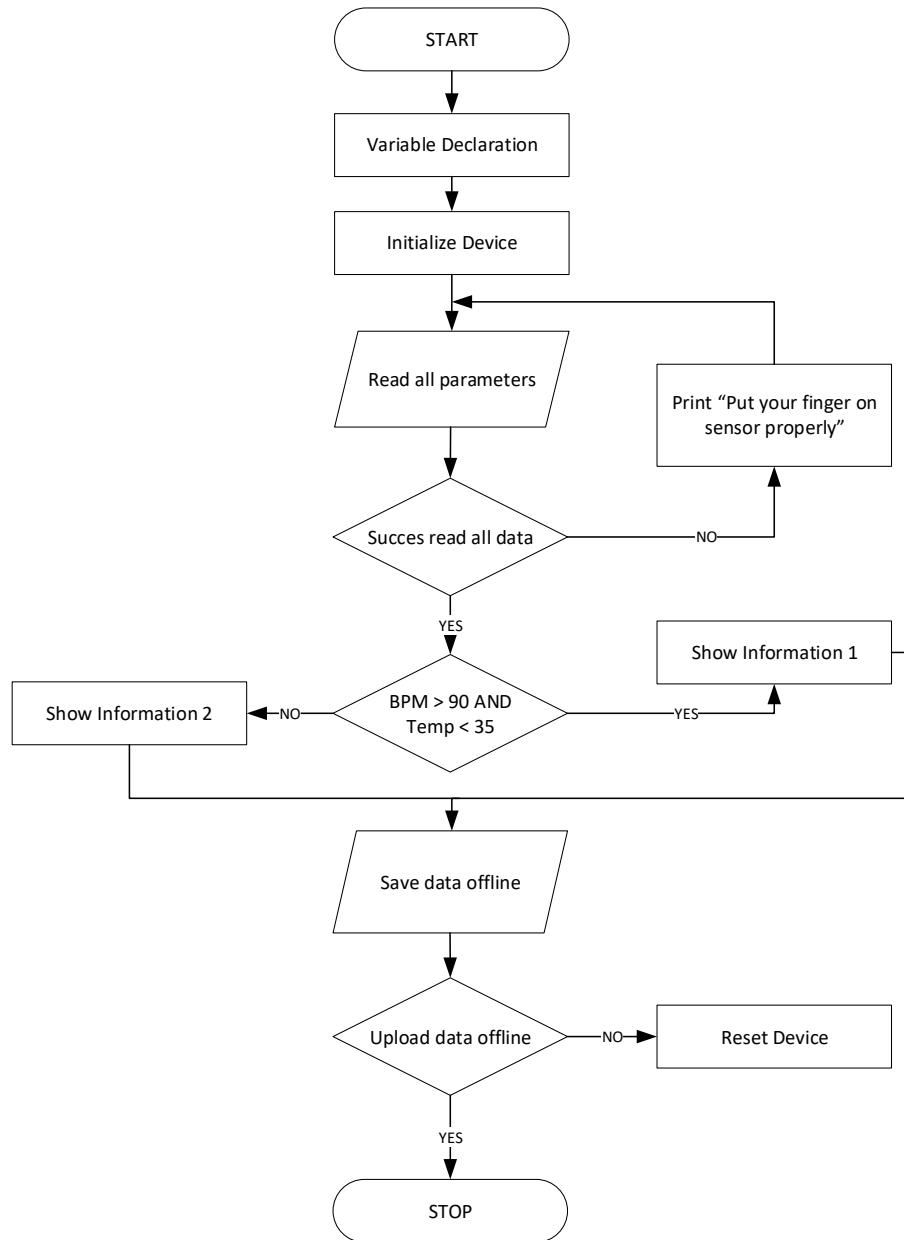


Figure 5. Flowchart of real-time stress detection and monitoring using IoT

3. RESULTS AND ANALYSIS

This section explains the research results and, at the same time, gives a comprehensive discussion. Figure 6 shows the experimental setup for data collection and five-minute subject data recording. The system then processes the recorded data, displaying the calculation results on the android application. The database can also be accessed as a spreadsheet via a web application.

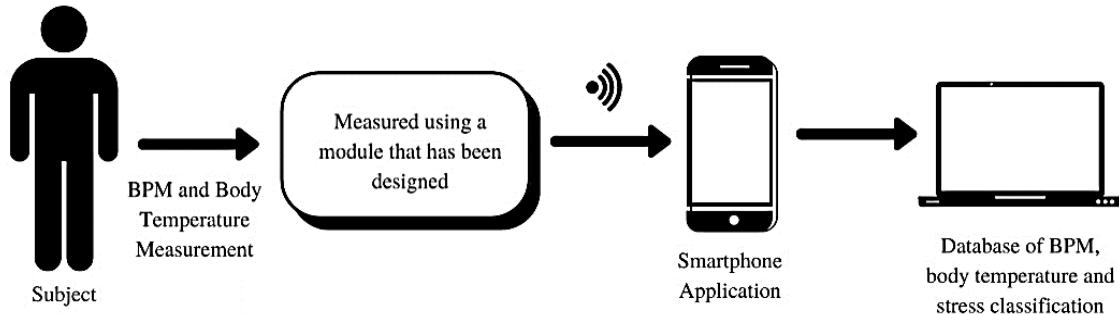


Figure 6. Data collection and experimental setup for real-time stress detection and monitoring using IoT

During data recording, the subject sat quietly. As seen in Figure 7, the subject holds the temperature sensor in the right hand and the HR sensor in the left hand. All subjects are recent graduates of Poltekkes Kemenkes Jakarta II. The measurement parameter and stress classification are shown in Table 1. The HR value and SPO₂ value are then classified using a decision tree classification (IF-ELSE THEN) using (1):

$$\text{If } \text{Temperature} < 33 \text{ AND } \text{HR} > 100 \text{ THEN "STRESS" ELSE "NO STRESS"} \quad (1)$$



Figure 7. Data recording process to collect HR and SPO₂ value

Table 1. Results of HR, temperature, SPO₂, and stress status classification

Subject	Physiological parameters			Status
	HR	Temperature	SPO ₂	
1	106	33.81	100	STRESS
2	68	34.81	99	NORMAL
3	98	38.8	99	NORMAL
4	76	33.7	99	NORMAL
5	72	33.81	98	NORMAL
6	82	35.1	96	NORMAL
7	92	37.62	98	NORMAL
8	74	31.31	96	NORMAL
9	73	39.94	97	NORMAL
10	85	35.19	97	NORMAL

Figure 8 describes the monitoring interface on the android cellphone. The data displayed is the value of HR, temperature, SPO₂, and information about stress status. If the sensor cannot read, it will display information to put the finger on the sensor.

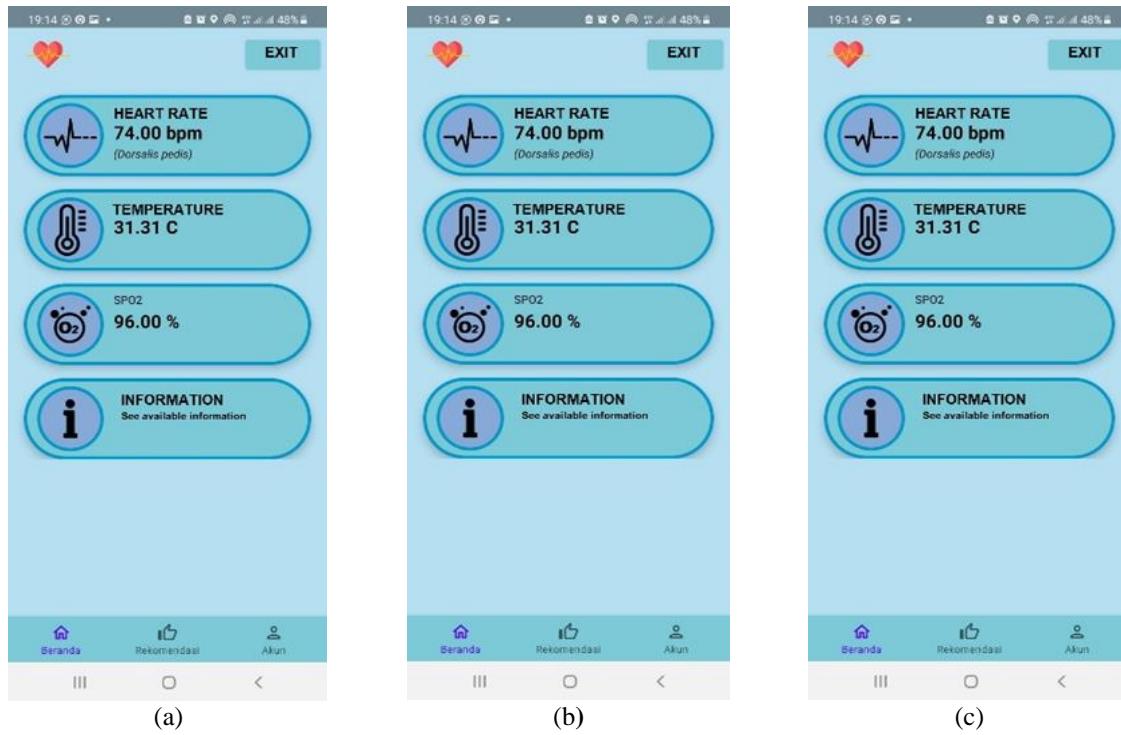


Figure 8. Real-time monitoring interface from Android Cellphone (a) application interface (b) information of measurement result and stress status (c) notification to put your finger on sensor

4. CONCLUSION

Using IoT to facilitate monitoring, this research proposed constructing a system to identify stress based on psychological signals. The parameter is derived from the body temperature, SPO₂, and HR values recorded by the DS1820 and MAX30100 sensors. The parameter test results demonstrate that the system can read these three parameters successfully. In addition, the Arduino system will evaluate the three metrics to determine if conditions are under stress or are expected. The test findings indicate that the system functions well in accordance with the stress parameter method. IoT technology transmits real-time stress monitoring result data to an Android smartphone. The test results indicate effective data transmission. Overall, the stress detection system functions effectively and can monitor real-time stress situations. This research can be expanded to improve the observed stress circumstances by including additional psychological measures, such as electrodermal activity (EDA) and HR variability (HRV).

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